



# Jupiter's Icy Moon Europa – Can It Harbor Life? Explorations with the Europa Clipper Mission

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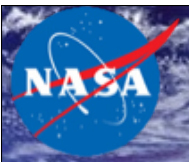




## Is There Life On Earth?

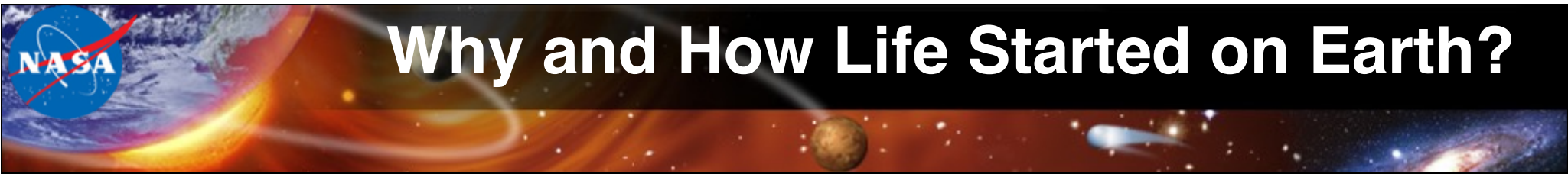
Yes, Of Course  
Bacteria, Plants, Ocean Life, Birds,  
Bees, Animals (including Humans!)  
and so on...





# There is Life on Earth!





# Why and How Life Started on Earth?

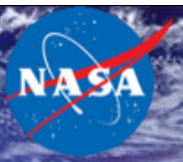
**Why is Life on Earth?**

**How Life Originated on Earth?**

**Is There Life Elsewhere in the Universe?**

NASA and other Space Agencies Worldwide are working  
Together to Answer the Second TWO Questions!





# Hello: Life Out There - Can You Hear Us?

Silence so far

But the Search for Life goes on





# Search for Life in Our Solar System

## The Ocean Worlds

Four Essentials for Life (that we know)

Water

Energy

Organic Matter

Minerals

## Ocean Worlds

World Definition:

- The Earth, together with all its countries, peoples, and natural features.
- The Planet that we (the Humans) live on.

New Definition: A Body in the Universe that is Special for Something



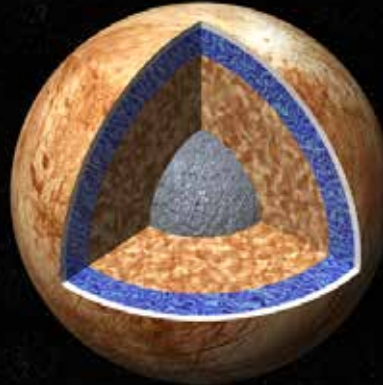


# What are the Ocean Worlds?

Those Bodies in our Solar System that Harbor Liquid Water



Earth



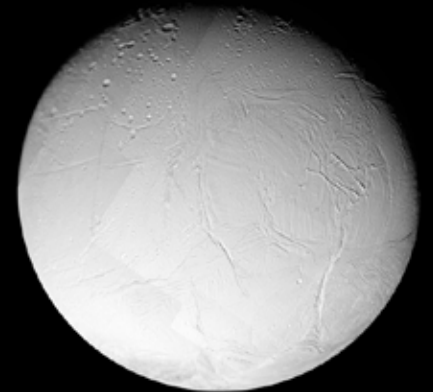
Europa



Ganymede

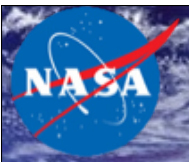


Titan

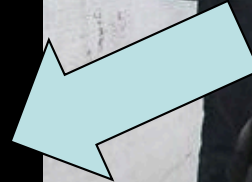


Enceladus





# Galileo Galilei Discovered Jupiter's Moons



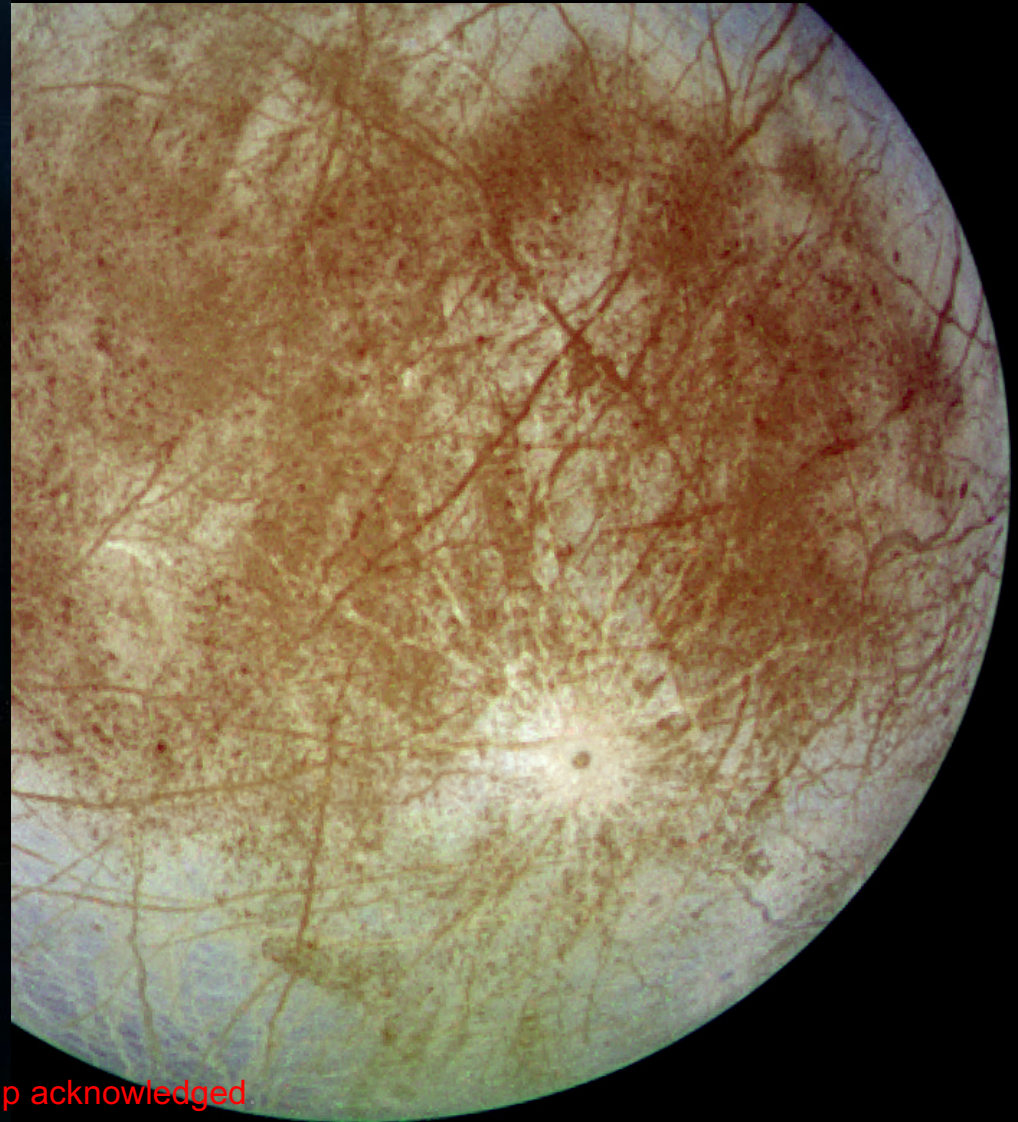
The Galilean Moons of Jupiter: Io, Europa, Ganymede, Calisto

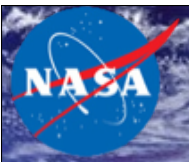




# Galileo Spacecraft @ Europa (1996)

Named after Galileo Galilei, the NASA Galileo Spacecraft took a close look at Europa and found indications for subsurface oceans!





# NASA JUNO Mission to Jupiter

The Dancing Moons: Io, Europa, Ganymede, and Callisto

Orbit Period Ratio: 1: 2: 4: 9.4





# Jupiter and Its Moons



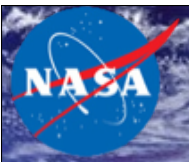
Europa

Io

Ganymede

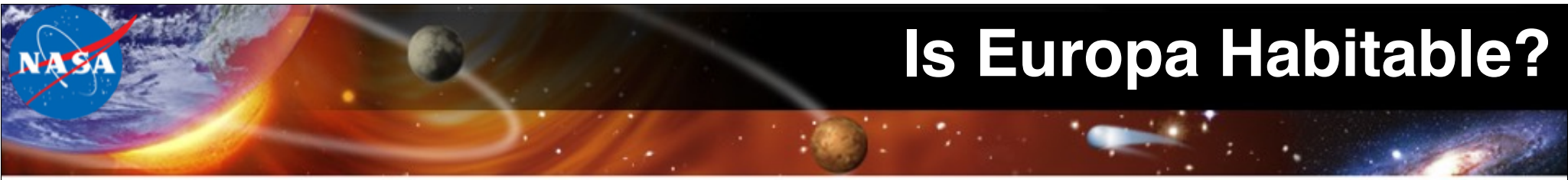
Callisto

Galileo spacecraft, 1995-2003



# What is Special About Europa?





# Is Europa Habitable?

## Key Ingredients for Life:

Liquid Water

Energy (Heat)

Minerals

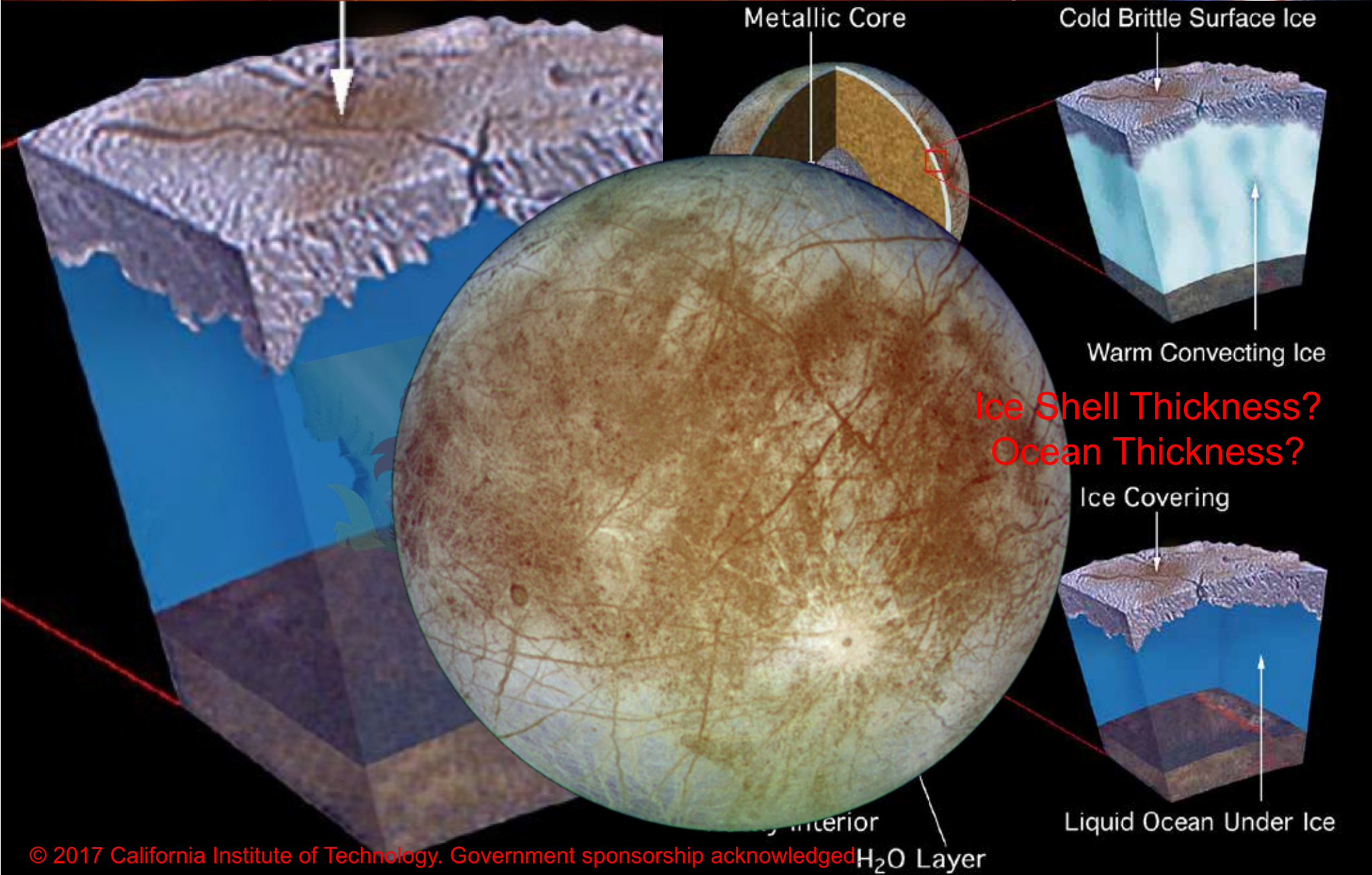
Organics

Very Likely that Europa has organics in the liquid oceans (brought externally by comet impacts or fractionated internally)

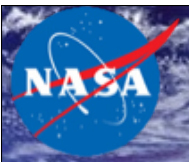
**Europa is Potentially Habitable!**



# What We Don't Know About Europa







# The Europa Clipper Mission

- Will provide most accurate data on the subsurface liquid water oceans!
- Will tell us if there are plumes venting from beneath!
- Will tell us whether there are tracers of Life
- Will tell us about shallow liquid water reservoirs
- Will provide information where we could dig below the surface to look for potential Life!

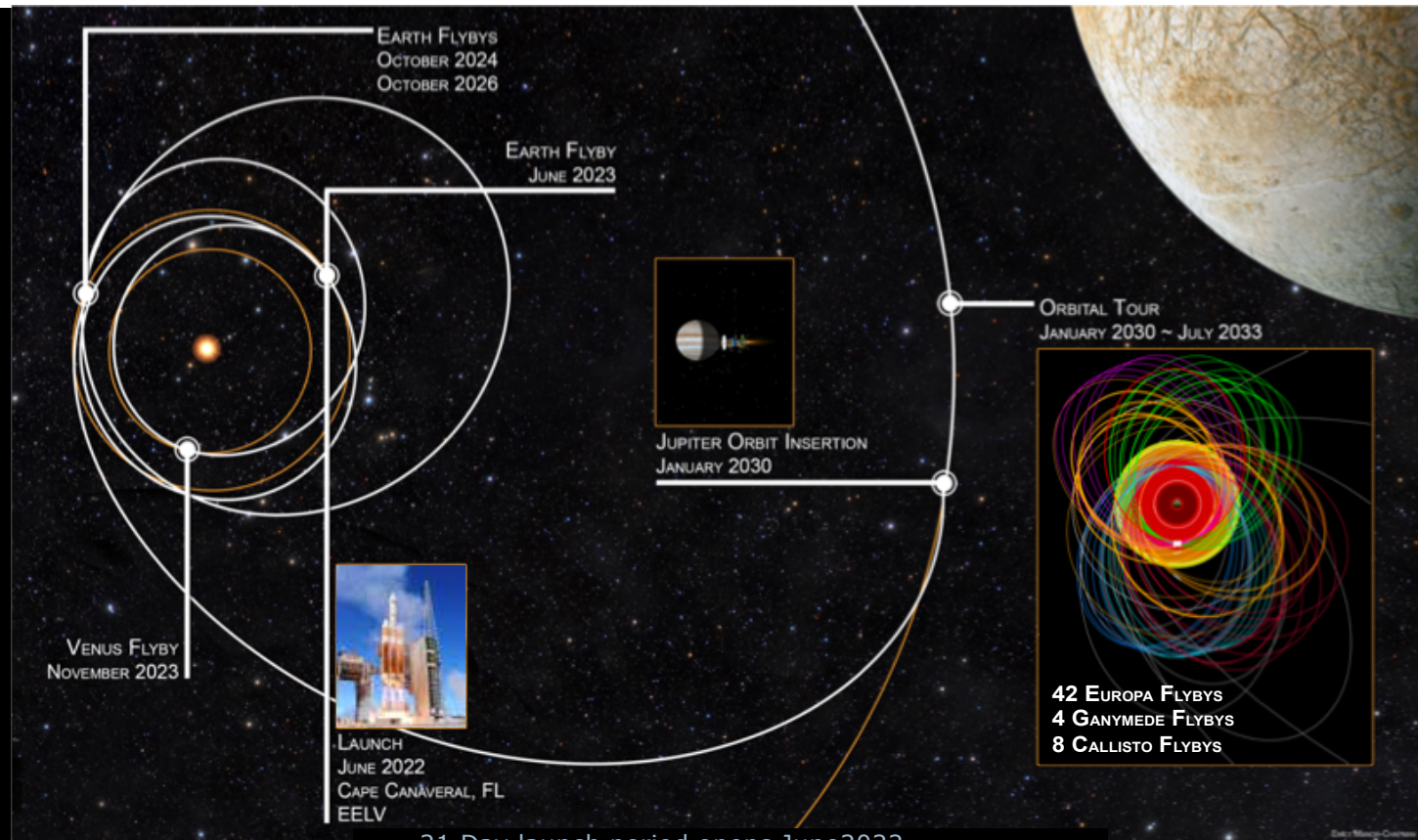
**Will Find Whether Europa is Habitable!**





# Europa Clipper Launch and Trajectory

## EVEEGA Interplanetary Trajectory EELV Launch Option– (Delta-IV Heavy, Falcon Heavy)



- 21 Day launch period opens June 2022
- Earth/Venus/Earth/Earth Gravity Assist
- Arrive Jovian System January, 2030 (7.5 Years)



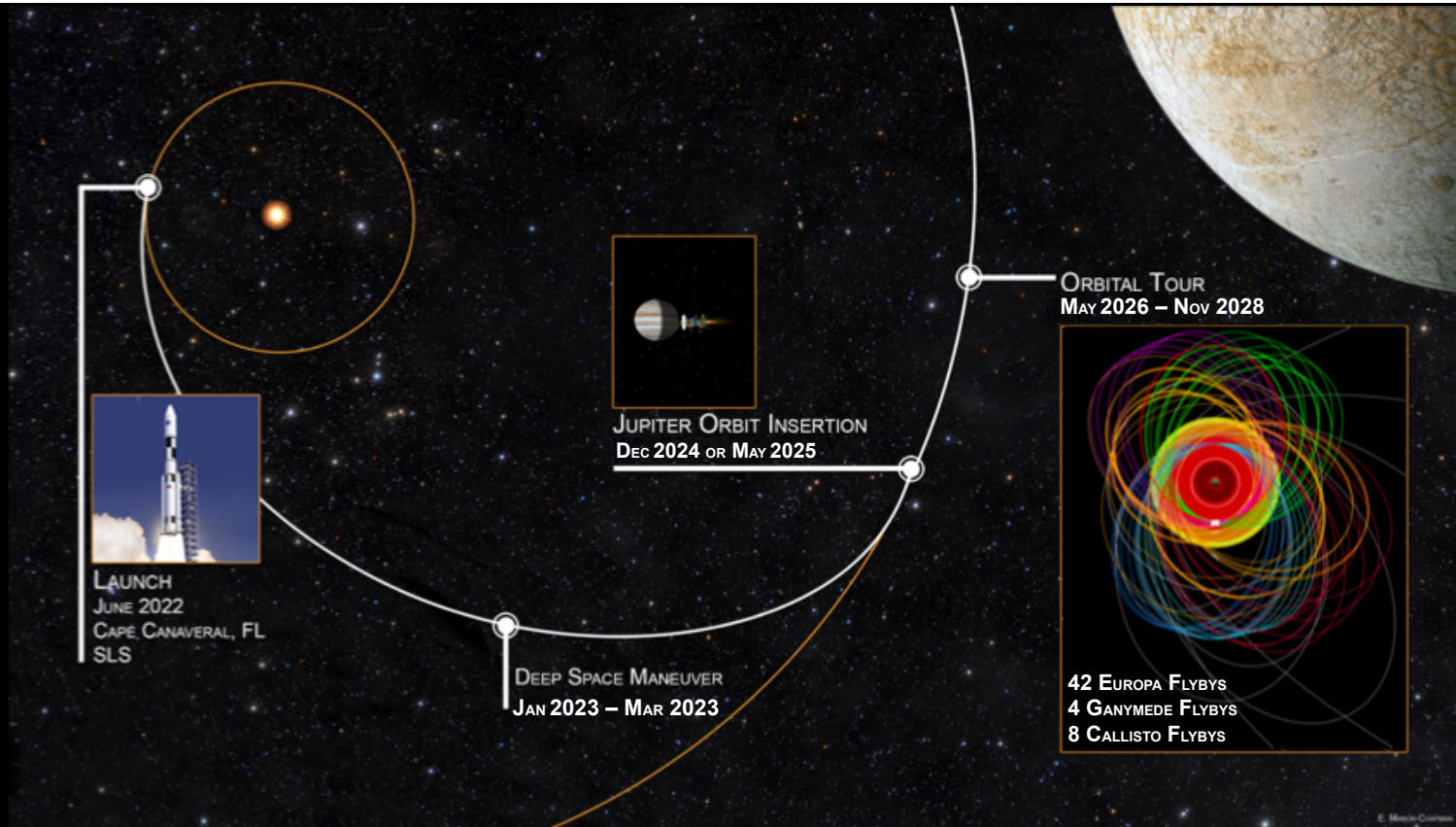


# Europa Clipper Launch and Trajectory

## Direct to Jupiter Trajectory SLS Launch Option



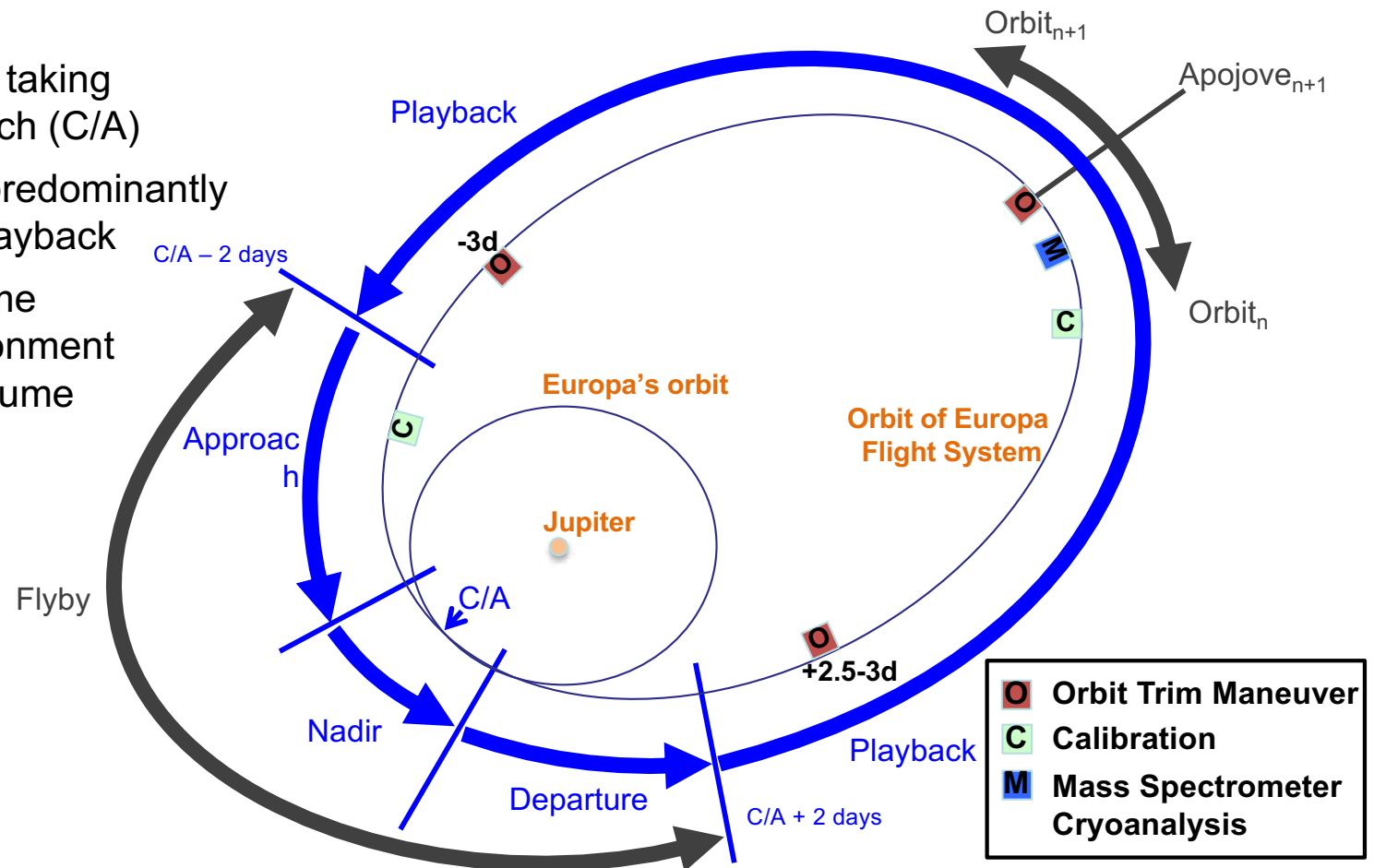
SLS Block 1B



- 21 Day launch period opens June 2022
- Arrive Jovian System March, 2025 (2.7 Years)



- Intensive science data taking around closest approach (C/A)
- Remainder of orbit is predominantly calibration and data playback
- Flyby strategy limits time in high-radiation environment and optimizes data volume acquired and returned

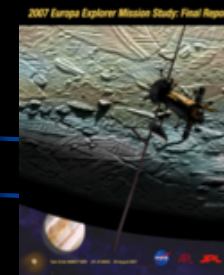




# The Journey of the Europa Clipper Mission

## A Flagship Mission & Generations (~35 Years) of Scientists

- Galileo Spacecraft takes a close look at Europa (1996)
- Europa Orbiter Science Definition Team (1999)
- A Science Strategy for the Exploration of Europa, COMPLEX, National Research Council (1999)
- NASA Campaign Science Working Group on Prebiotic Chemistry in the Solar System (1999)
- New Frontiers in Solar System Exploration, Decadal Survey, (2003)
- Jupiter Icy Moons Orbiter (JIMO) Science Definition Team (2004)
- Scientific Goals and Pathways for Exploration of the Outer Solar System, OPAG (2006)
- NASA Solar System Exploration Roadmap (2006)
- Europa Explorer (EE) Report (2007)
- Jupiter Europa Orbiter Mission Final Report (2008)
- Europa Study Report (2012)



**After 19 Years since Galileo Mission met Europa,  
Rigorous Science Data Analysis, Several Science Definition  
Reports, and Meticulous Planning,  
Europa Clipper Mission was born in 2015.**



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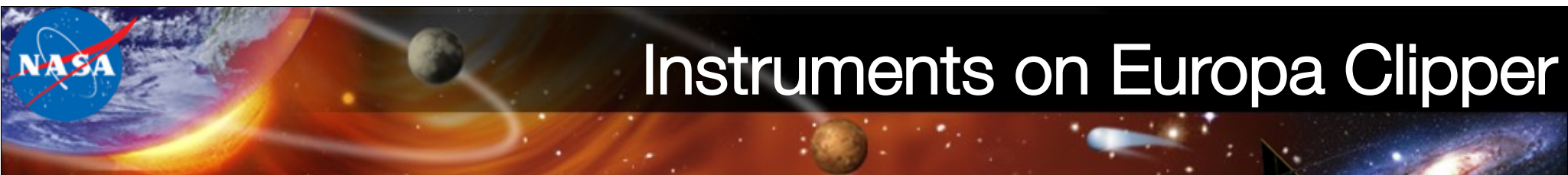


# Europa Clipper Mission Team



**Europa**  
**Project Science Group Meeting #1**  
**August 4, 2015**





# Instruments on Europa Clipper

**Europa-UVS**  
*UV Spectrograph*  
surface & plume/atmosphere  
composition

**MASPEX**  
*Mass Spectrometer*  
sniffing atmospheric  
composition

**EIS**  
*Narrow-Angle Camera +  
Wide-Angle Camera*  
mapping alien landscape in  
3D & color

**SUDA**  
*Dust Analyzer*  
surface & plume  
composition

*Radiation Science  
Working Group*  
radiation environment

**ICEMAG**  
*Magnetometer*  
sensing ocean  
properties

**PIMS**  
*Faraday Cups*  
plasma environment

**E-THEMIS**  
*Thermal Imager*  
searching for hot spots

**MISE**  
*IR Spectrometer*  
surface chemical  
fingerprints

**REASON**  
*Ice-Penetrating Radar*  
plumbing the ice shell

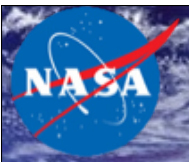
*Gravity Science  
Working Group*  
confirming an ocean

1/10/17

● Remote Sensing

● In Situ





# NASA's Flagship Mission to Europa



# Ice Spectroscopy Laboratory (ISL) @ JPL



Science & Technology  
Office of the Chief Scientist and Chief Technologist

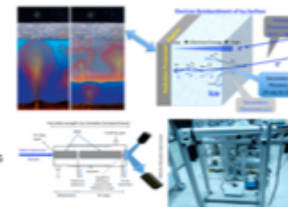
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## Ice Spectroscopy Laboratory (ISL)

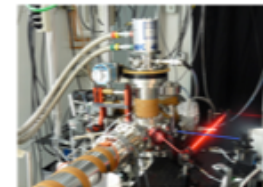
At the Ice Spectroscopy Laboratory (ISL) of JPL, our goal is to understand how ices and organics evolve in the Universe (interstellar, circumstellar, outer planets, inner solar system, and Earth) and use this knowledge to support present and future NASA missions. Our research at ISL currently focuses on comets, Europa, and Mars. We derive spectroscopic properties of ices and organics at a wide variety of wavelengths (0.1 - 500 microns) and temperatures (5 - 150 K). We also study spectral variations in ices due to radiation bombardment, primarily using ultraviolet photons and electrons of energies 1-100 keV (onsite) and from 10-30 MeV (in collaboration with NIST).

A wide variety of starting ice compositions are used, including water, methane, methanol, ammonia, carbon dioxide, salts and more complex organics. Temperatures, pressures, and radiation environments are also tunable in our experiments, enabling studies of a variety of space-like environments: the Interstellar Medium, the Kuiper Belt and outer Solar System bodies, inner Solar System, and Exoplanet Atmospheres.

At ISL, we recently developed in-situ two-step laser ablation and ionization time-of-flight mass spectrometry (2S-LA-TOFMS) that has unique abilities to analyze the composition of solid material, including ices in hands-off mode - at the sample's native temperature. With the help of this instrument our research showed for the first time that complex radiation chemistry is occurring even in the coldest parts of the Universe. We are now in the process of miniaturizing the 2S-LA-TOFMS for in-situ organic detection on Mars and other bodies in our Solar System, including asteroids and comets.



ICE HEART (Ice Chamber for Europa High-Energy Electron And Radiation Environment Testing) built to reproduce Europa's trailing hemisphere radiation and temperature conditions in order to determine how the primary electrons (up to 30 MeV) and the secondary X-rays (Bremsstrahlung) penetrate through surface ice of Europa and damage organic matter - including potential life - if present.



2-step laser ablation and ionization time-of-flight mass spectrometer (2S-LA-TOFMS) developed at the Ice Spectroscopy Lab (ISL) of JPL. This instrument is capable of analyzing a wide variety of molecular composition of ices, organics, metals, salts, etc. An infrared laser is fired through a lens, generating a predominantly neutral plume of material. This plume is then ionized with an ultraviolet laser ionizing which ions are then analyzed in a mass spectrometer. Our new PicoTOF instrument is of this length and is aimed to be used as a compact, controlled device for surface organic analysis.

### Personnel / Contacts:

- Murthy S. Gudipati
- Bryana Henderson
- Benjamin Fleury

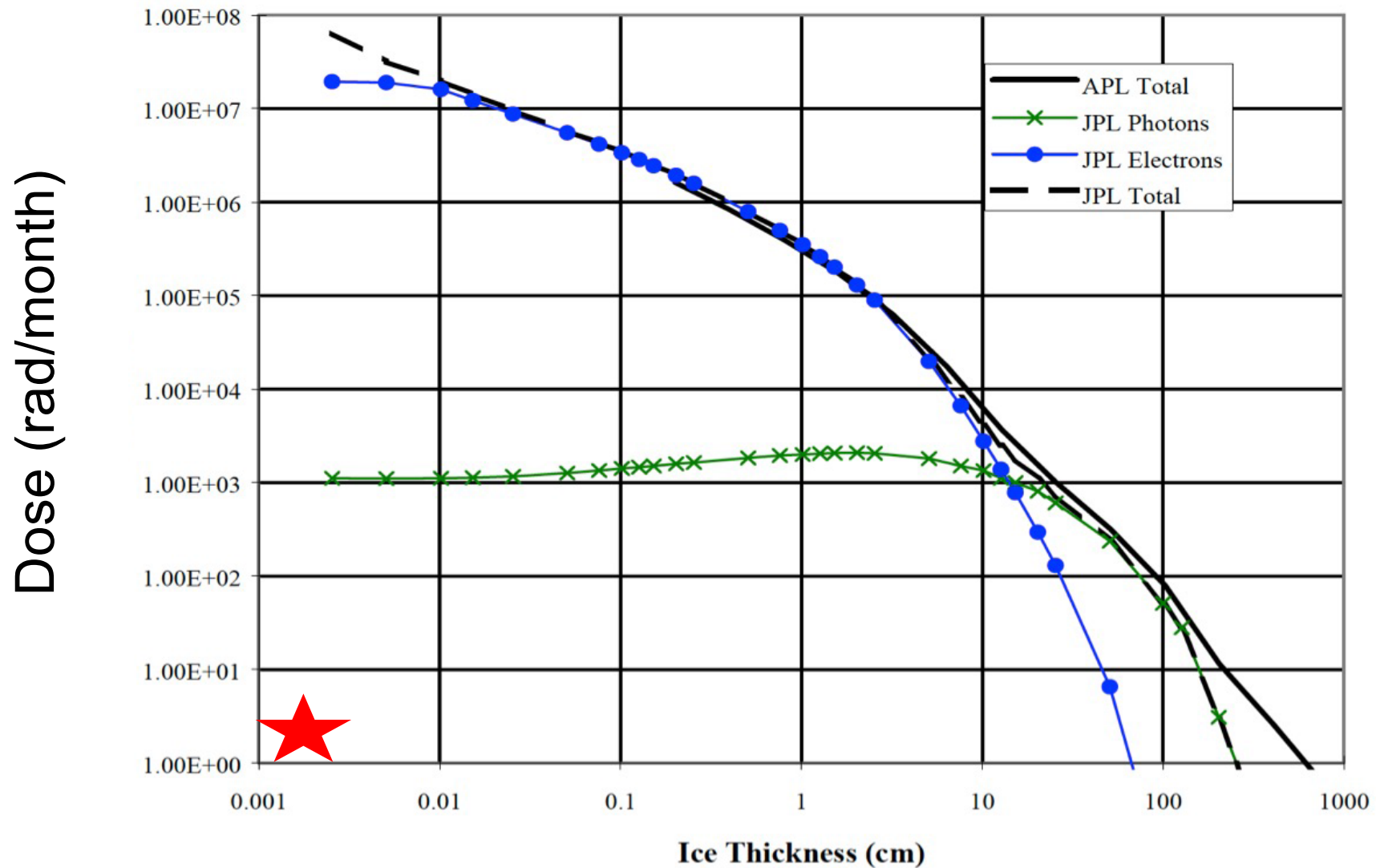
### Ongoing Research Projects:

- **JPL Research & Technology Development:** High Energy (MeV) Electron Damage Depths of Organics in Ice Analogs of Europa's Surface
- **NASA SSW:** Europa's Photochemical Sulfur Cycle
- **NASA PA:** Understanding the Near-Surface Atmospheres of Icy Bodies: Role of Photoionization of Organic Impurities in Icy Surfaces
- **NASA PICASSO:** Towards Miniaturization of Instrumentation for In-Situ Organic Detection: Hands-Off PicoTOF
- **Europa Mission:** SUDA Instrument

Simulations of High Radiation Environment of Europa



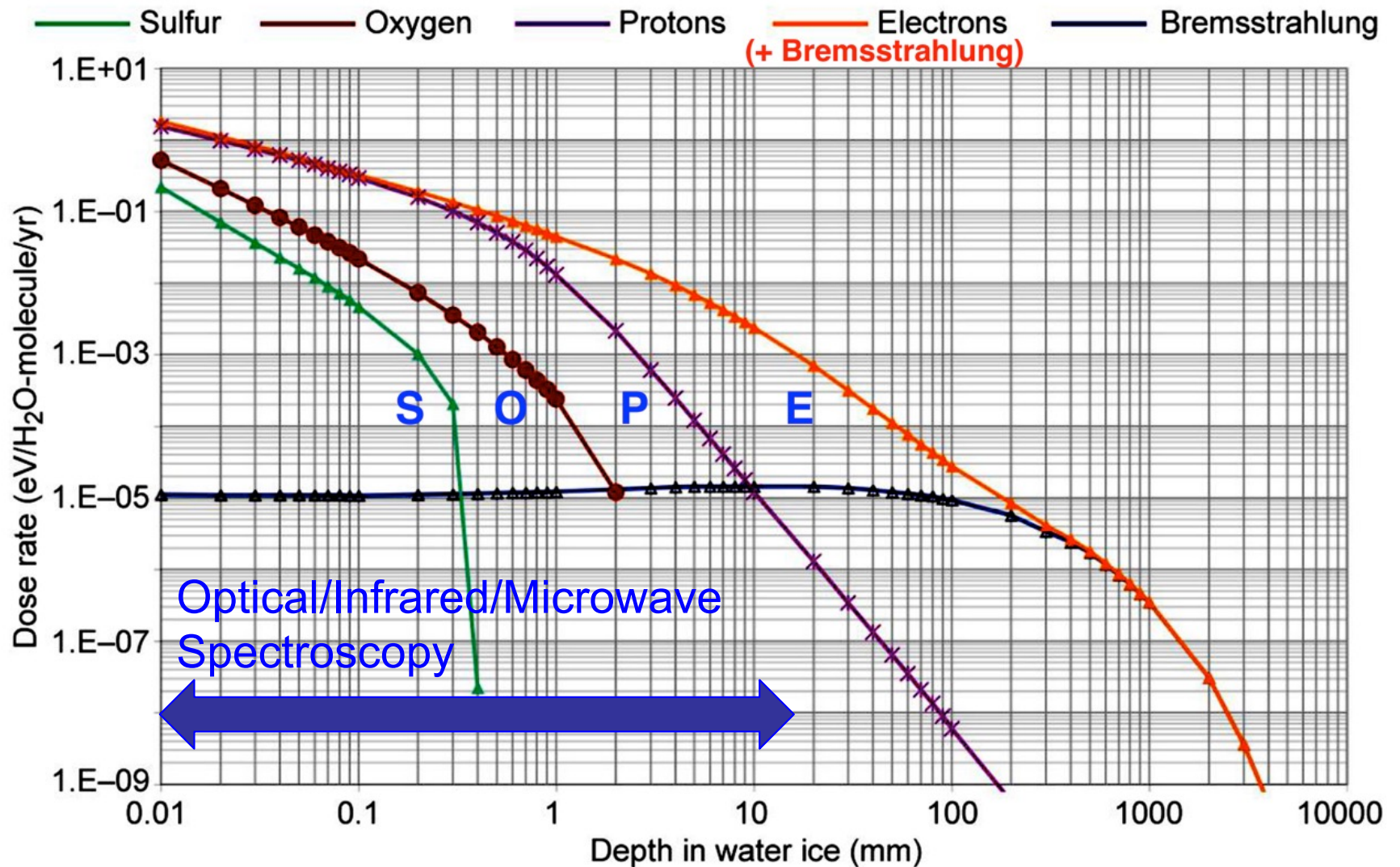
# Extremely Harsh Radiation on Europa



Maximum permissible dose for humans (astronauts) = 25 rem/year



# Europa's Surface is drenched with Radiation

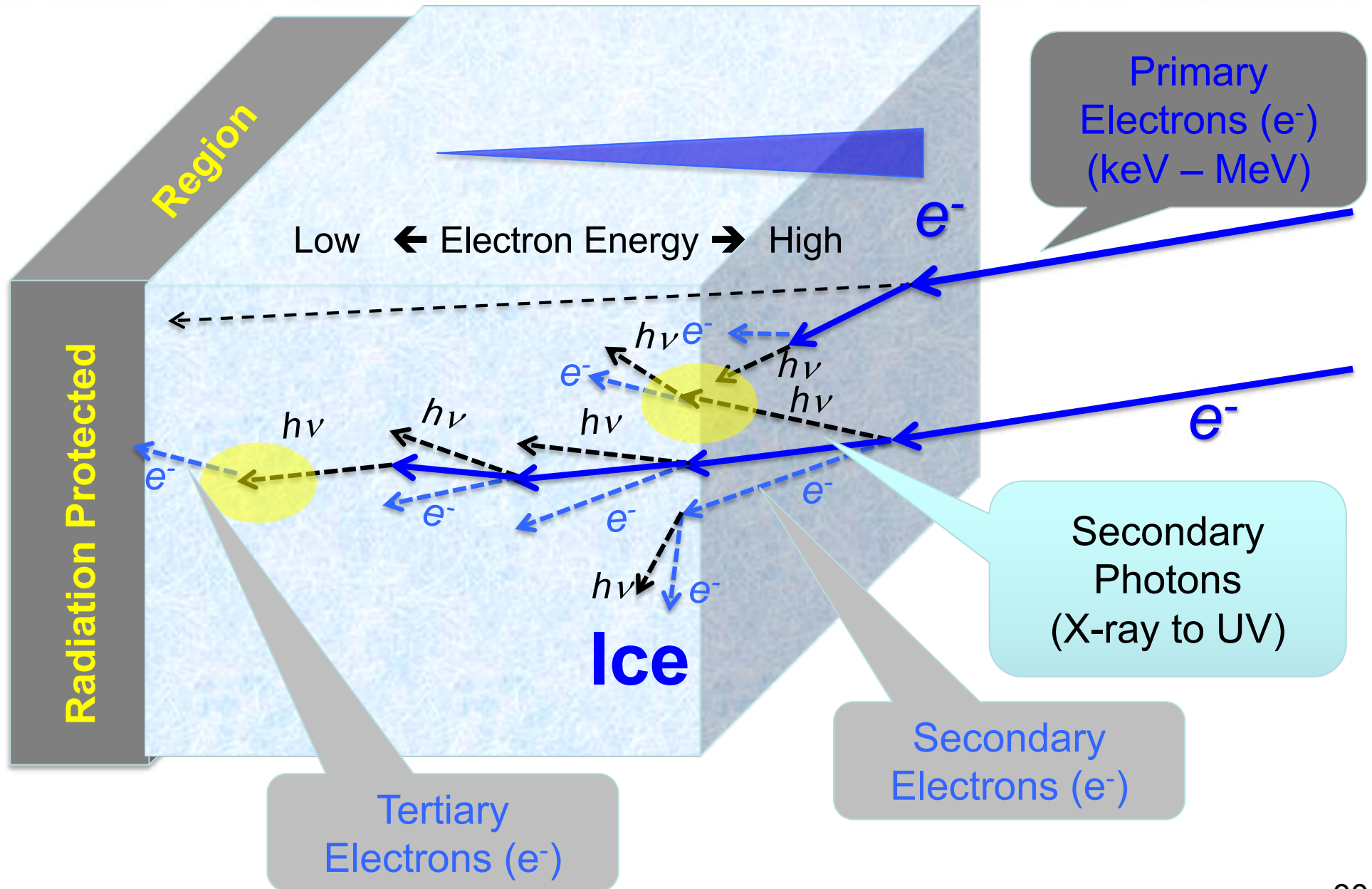


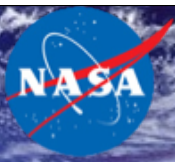
Plot from: Paranicas et al. (2002)



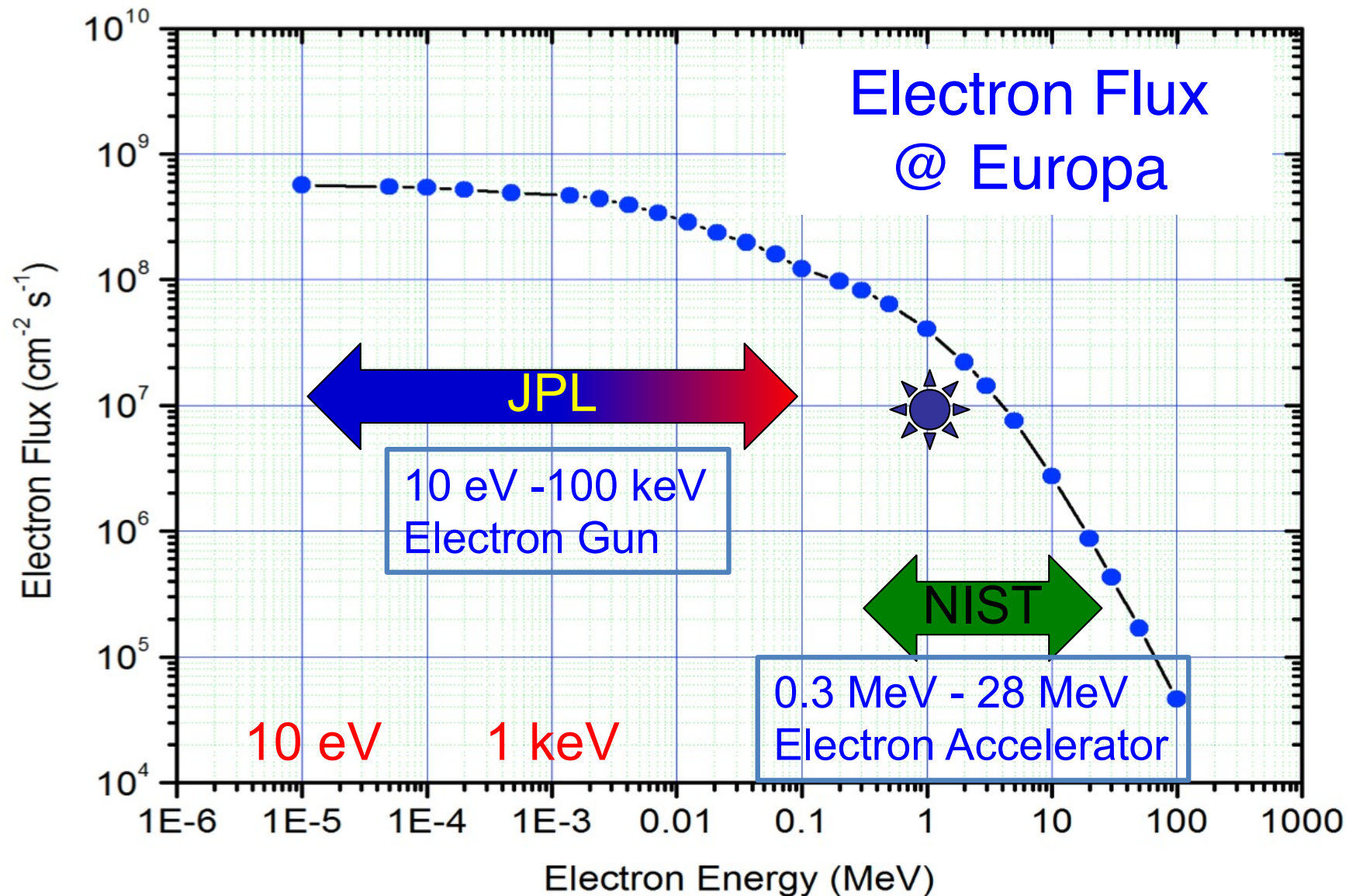


# Including X-rays and Gamma Rays

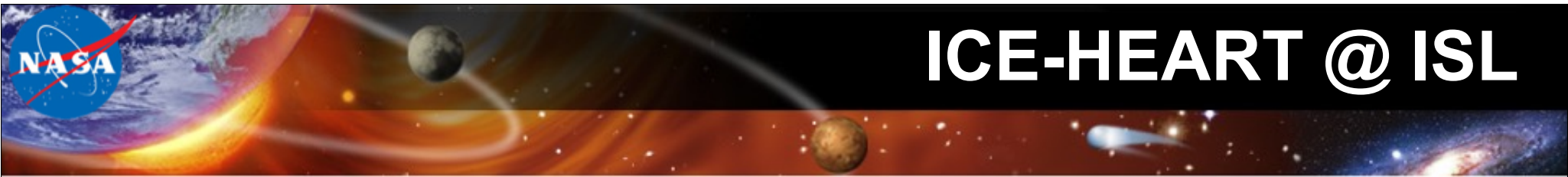




# Electron Radiation at Europa: Laboratory Simulations on Earth



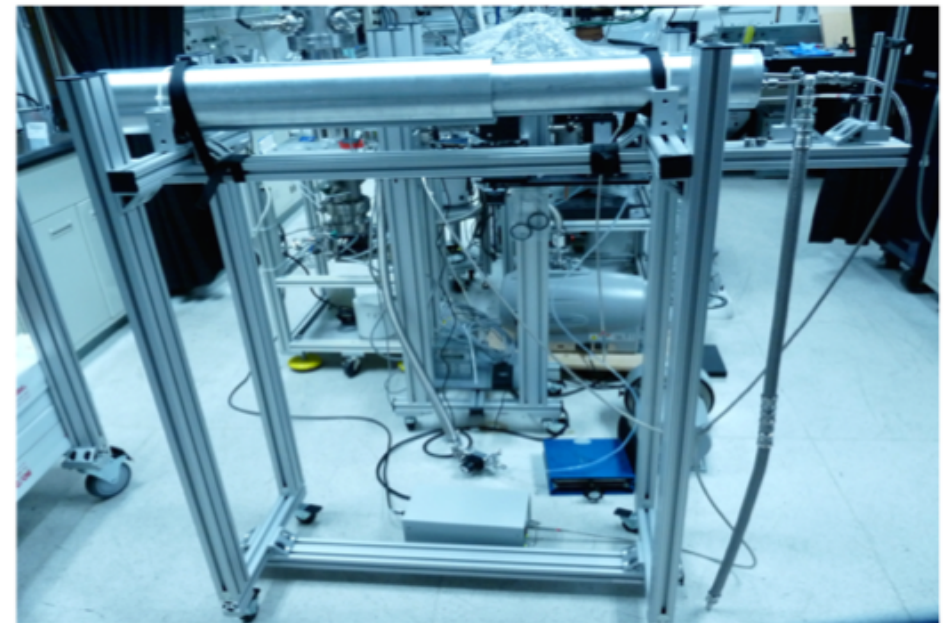
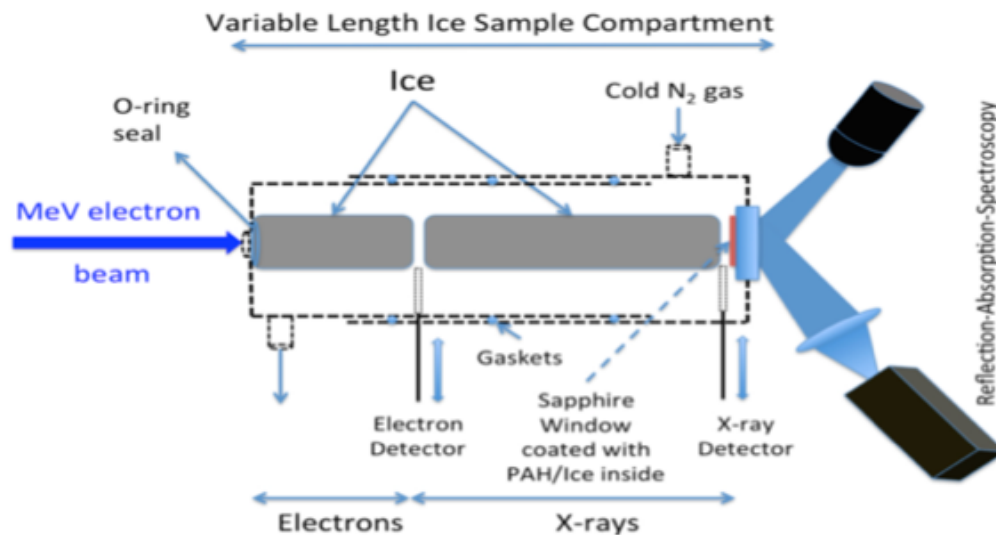


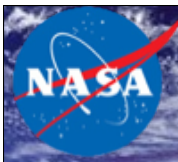


# ICE-HEART @ ISL

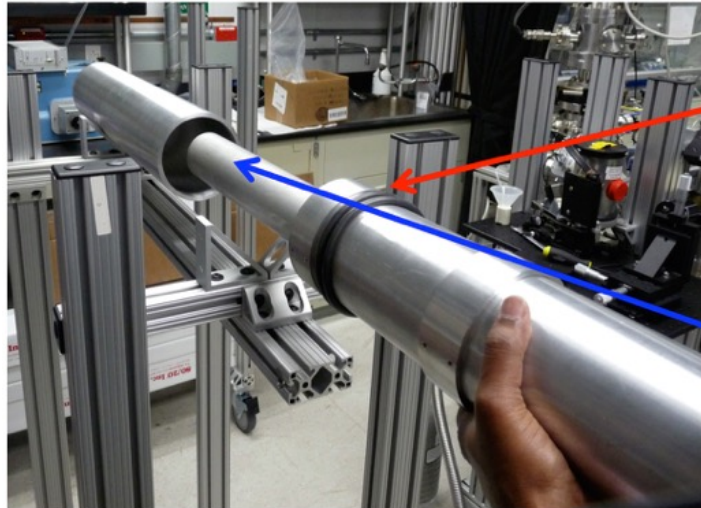
(Ice Chamber for Europa's High-Energy Electron And Radiation-Environment Testing)

## Designing and building ICE-HEART for Europa





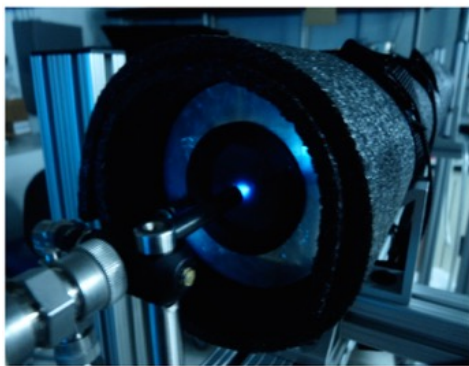
# ICE-HEART Europa Surface Ice @ 110 K



Outer Telescope with vacuum seal O-rings.

Inner 2.5-inch diameter tube for water ice frozen in the tube or loaded as crushed powder.

110 K  
(-163 °C)



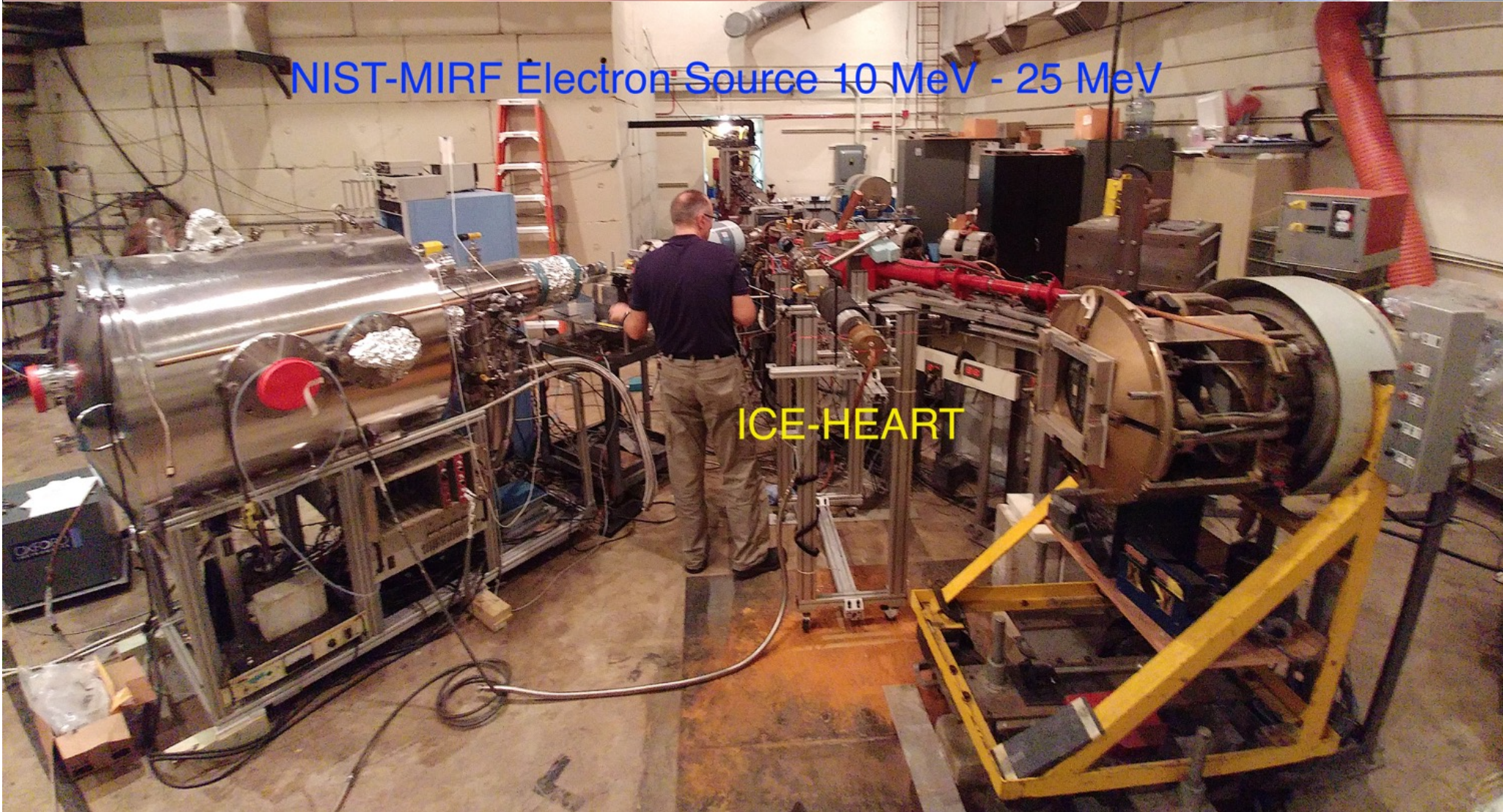
Insulated for 100 K operation  
Using liquid nitrogen cooling.





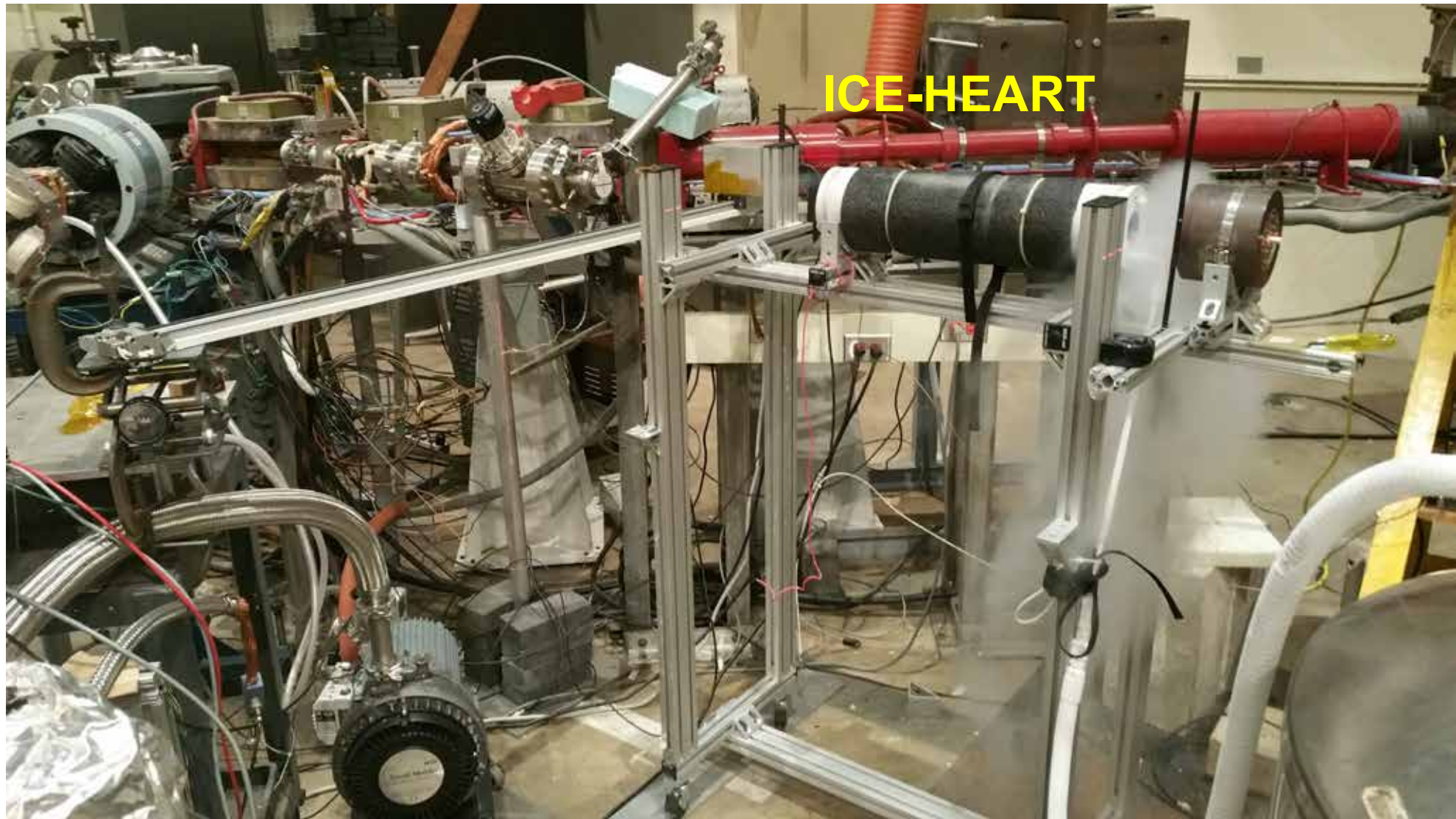
# NIST Electron Sources Cover 300 keV to 28 MeV

NIST-MIRF Electron Source 10 MeV - 25 MeV





# NIST Electron Sources Cover 300 keV to 28 MeV



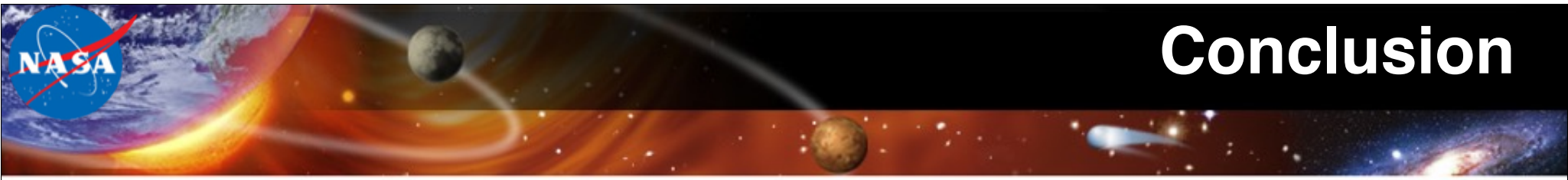




# ICE-HEART Crew in Action @ NIST MIRF



Ice Sample Handling in (subsequent to)  
High-Radiation Environment



# Conclusion

Europa is “potentially” Habitable

NASA’s Flagship Mission to Europa  
(Europa Clipper)

Will determine Europa’s Habitability

Europa has one of the harshest Radiation  
Environment

Europa Clipper Mission is a Daring Mission  
Into the harshest Environment Ever!

How Deep Below the Ice Surface are the Oceans?  
Are there Pockets (Lakes) near the Surface?  
Are there tracers of Life?  
Are there plumes like Old-Faithful on Europa?  
And so on...



# Thank You

